
BULLETIN No. 13

Vol. II

□ □ **1924** □ □

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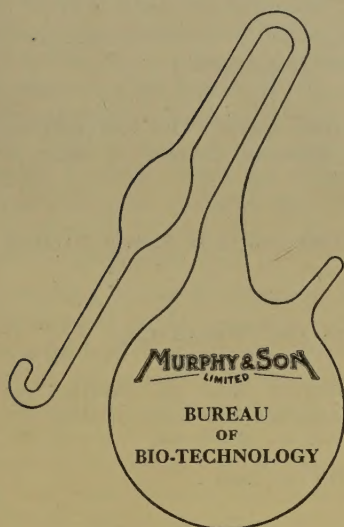
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The Khapra Beetle

ITS INFLUENCE ON THE MOISTURE CONTENT OF MALT IN STORE

DURING the present year we have continued to receive samples of barley and malt which we have had to report infested with *Khapra*, and in some cases the samples have represented new consignments of Indian barley. The least that can be said is that this is a disquieting feature of the importation of a grain which is again finding favour on the English market. The maltster, and in turn, the brewer, each has a sufficient number of indigenous pests to contend with, without augmentation from colonial sources, and it is a matter for serious consideration whether the advantages of price, character and usefulness are not more than counterbalanced by the risk of insect infestation and its potentiality for subsequent loss.

This must be a matter of concern to the shipper, the gravity of which appears not yet to have been recognised. On the other hand, the brewing trade is at last fully alive to the danger of *Khapra* development in this country, and the brewing press is active in spreading information which will facilitate the recognition of the beetle and its damage. An article on this subject by the present writer, written at the request of the Editor of the *Brewing Trade Review*, appears simultaneously with this and, by the courteous permission of the Editor, we reprint it on p. 117 of this issue of the *Bulletin*.

Since this Bureau became vigilant in the campaign against the *Khapra* beetle* we have received a good deal of correspondence on the subject, much of which we are unable to make use on account of its private character, but we have recently received particulars of some valuable observations made by Mr. H. Stanley Taylor, of Bath, which we are permitted to publish. We consider

* *Bulletin Bureau of Bio-Technology*, No. 2, 1921.

ourselves fortunate in being able to present details of practical experience gained under works' conditions together with results of a quantitative nature which add substantially to our knowledge of the depreciation of malt brought about by the action of *Khapra*.

This information will be best communicated in Mr. Taylor's own words, after pointing out that his letter opens with reference to some remarks offered in a discussion of a paper dealing with this question, read before the Institute of Brewing, in London, in 1921—see *Brewing Trade Review*, (loc. cit.) and this *Bulletin*, p. 121.

Mr. Taylor writes, under date October 10th, 1924:—

“ I have added experience in connection with the particular infestation to which I then drew attention. The Maltings in question were owned by a well-known West of England Brewery Company. The Malt Bins were surrounding what is generally known as a shaft kiln.

The Brewery Company many years ago felt that it was desirable to line the brick walls inside the bins with matchboarding; evidently the idea was to keep the malt away from the brick walls.

The floor of the bin is $1\frac{1}{4}$ in. red deal, iron tongued, and beneath the floor are two furnaces, so that the wooden floor has shrunk very much.

Through bad arrangements for cleaning foreign barley, the malting became infested with the *Khapra* beetle, and eventually they migrated to these bins. I feel sure they migrated, as they were not brought there in the ordinary course of manufacture of the malt. Behind this matchboarding they found a most delightful breeding ground. Undoubtedly, as Mr. Mason has stated, these insects have the power of hibernating to a very considerable extent.

Several years ago the malt in these bins became so badly infected with the insects that I was asked by the Board of Directors to investigate the matter, together with their Brewer. At that time I was a Director of the Company. We made a thorough investigation, and I came to the conclusion that these insects were behind the matchboard. We decided to rip

off the whole of the matchboard: then was disclosed to our view millions of these insects. I do not think it would be an exaggeration to say that we carried out of the bins two or three sacks full.

The boards having been put on battens, there was a considerable cavity between the boards and the bricks. I thought at the time that I had cured the trouble. This summer, however, the pest broke out again in most alarming proportions. During September this year we were able to clear the whole of the malt from the bins—four in number. The kiln shafts ascend between each pair of bins, and there appeared to be a very nice even surface on these brick shafts. It had been whitewashed and looked perfectly innocent so far as *Khapra* beetles were concerned. You can imagine that a bin of this description is not particularly well lighted. On examining this shaft I discovered that the smooth surface consisted of some very thick sheets of asbestos, pretty well $\frac{1}{2}$ in. thick, sheets about 4 ft. by 3 ft., joints most carefully butted. In one or two directions I could see small cracks or apertures. I decided to pull away one of these sheets, and there we found millions of *Khapra*.

The sheets were nailed to battens, causing a cavity, though not so big a cavity as there was behind the board and the bricks. I took down the whole of these sheets and collected more than four bushels of live and dead *Khapra*.

It is very clear therefore that the source of the second infection was the cavity behind the asbestos sheets.

It is extraordinary how these insects will penetrate the smallest opening. This, then, is the history of the two bad infections we have had in these maltings.

I can now approach the matter from another point of view altogether, and that is the relationship of moisture to *Khapra* and *Khapra* to moisture. Here I confess I am baffled. My favourite theory up to the present has been that it was not possible for *Khapra* to develop in malt or grain which had a moisture content of less than 2 per cent.

My theory has always been that the moisture was communicated to the grain or malt by outside influences and this produced conditions favourable to the development of the latent insect in the grain.

When first we drew malt from this bin there was nothing abnormal about the moisture content. The bin held about 400 qrs. After having drawn from the bin 200 qrs. of malt in which there was no great evidence of *Khapra*, the next 50 qrs. of malt showed the presence of the insect. The next 50 qrs. of malt showed more *Khapra*, and for the first time a rise in moisture content.

The last 100 qrs. drawn out of the bin disclosed an enormous quantity of *Khapra* and a very high increase in moisture content.

I was able to attend to this matter myself, and I found that the moisture content of the malt was higher where it was absolutely impossible for the malt to be influenced by outside conditions than in that portion of the malt which might have been influenced by outside conditions.

As I have stated before, the malt was stored on a $1\frac{1}{4}$ in. board floor, iron-tongued; beneath the floor was the kiln house, no ceiling, no air pocket or buffer: there was simply ordinary atmosphere, then $1\frac{1}{4}$ in. board, then the malt.

I have frequently found that malt stored under these conditions up to about 6 in. in depth is capable of absorbing in nine months at least 2% of water. The higher you go into the malt the lower the moisture content. I could give figures step by step in this direction, but for the purpose I have now in view it is not necessary to go further than to say that the moisture content of the malt on the floor was 3.3%.

The moisture content of the malt where it was impossible for it to be influenced by outside agencies, as well as in the centre of the worst infested area, varied between 7 and $7\frac{1}{2}$ %.

Are we therefore to believe, or try to believe, that these insects have the capacity to produce water?

I estimate in this bin that 80 qrs. of the malt showed a moisture content of 5.4. When the malt was put into the bin the average moisture content was 2%. We have therefore a rise in moisture content in 80 qrs. of malt of 3.4%. Now, 3.4% of 80 qrs. equals 913 lbs. and 913 lbs. equals, say, 91 gallons of water. A fractional part of the rise in moisture content can be attributed to uptake in moisture through the wooden floor. I am conducting several experiments in connection with this matter in our laboratory.

We started to fill this particular bin on December 19th, 1923, and it was filled by February 23rd, 1924. We commenced delivery early in February and the whole of the malt was cleared from the bin by the middle of June, 1924. The bulk of it was delivered in April, May and June.

Another bin of about 400 qrs. was charged between April 18th and May 5th, 1924, with the exception of one wetting, which was put into the bin on February 6th, 1924. Early in October, 1924, we noticed deliveries increasing in moisture content. After an examination of this bin it was decided to re-dry the balance of about 150 qrs.

The average moisture content of the 150 qrs. was 4.4%, and the moisture content of the malt actually on the floor 3.3%, whilst the moisture content of the worst infested area was 5.8%. The average moisture content of the malt as put into bin, 1.9%.

150 qrs.	4.4%
Average 150 qrs. put in	1.9%
Difference	2.5%

$2\frac{1}{2}\%$ of the 150 qrs. = 3.75 qrs. = 1,260 lbs.
= 126 gallons of water.

(Signed)

H. STANLEY TAYLOR."

The Khapra Beetle in British Maltings *

THE continued influx into this country of the dreaded *Khapra* beetle through the agency of last crop shipments of Indian barley, as well as through grain shipped from African ports, makes it desirable once again to call attention to the dangers which may arise through the presence of this insect in the maltings and breweries of this country. The *Khapra* beetle is now being constantly reported from Continental maltings where its depredations have given rise to much anxiety. The most recent paper on the subject is that by Voelkel (*Arbeiten d. Biologische Reichsanstalt f. Land.—u. Forstwirtschaft*, 1924, No. 13), which, on account of its special importance to the brewing industry has been very fully summarised in the daily organ of the German Brewing School in Berlin (*Tageszeitung für Brauerei*, No. 208, Sept. 4th, 1924).

In the first notice of this insect in connection with its occurrence in English, and indeed in European maltings which appeared in *Bulletin* No. 2, *Bureau of Bio-Technology*, Jan., 1921, it is referred to under the scientific name, *Trogoderma khapra*, and the various names under which the same insect has masqueraded in India and elsewhere in times past were fully discussed. The name there used is that given by Mr. G. J. Arrow, of the Entomological Department, British Museum, who had recently re-described the beetle (*Annals Mag. Nat. Hist.*, XIX., 1917). When giving this name, however, Mr. Arrow was unaware that the name *Trogoderma granarium* had been applied by a Dutch entomologist, in 1898, to several specimens which had at that date found their way to Amsterdam. Mr. Arrow has since been in correspondence with the author and has satisfied himself that the insect is the same species and that this name must take precedence over any others. It is for this reason that

* MASON, F. A. *The Brewing Trade Review*, December 1st, 1924, p. 504.

the insect will be found referred to in the Continental publications above-mentioned under the name *Trogoderma granarium* Everts.

Mr. Arrow, to whom the present writer is directly indebted for information upon the thorny subject of taxonomy, as the name-study of organisms is termed, thinks it by no means improbable that a still older name has been given to it in America, and next year, possibly, if we wish to be meticulous, we may be under the necessity of calling the insect by some other scientific name. *Khapra* is the name commonly used in India, and it is the one that may always be used without confusion. It is an insect which differs materially, particularly in the larval condition, from any other insect likely to be found in maltings and breweries. It is in the larval condition that the insect is to be feared, and, fortunately, it is this form that is most readily detected in any case of infestation. In some stages of its development the hairs at the posterior end of the larva are very long, occasionally half as long as the whole insect. This very hairy appearance is quite a sufficient character to enable anyone to decide as to its identity. The individual hairs are jointed and barbed, and these provide the creature with means of adhering to almost any kind of surface on which it may find itself. Particularly is it difficult to dislodge the grub from sacks to which they remain tenaciously attached after prolonged shaking and beating, and there is ample evidence that distribution from maltings to brewery, from town to town, and throughout the country is accomplished unobserved in the meshes of the carriage sack. It is a mistaken and mischievous idea that a maltings is liable to a visitation of *Khapra* infection only if consignments of Indian barley are being received or have been previously received into the maltings; on the contrary, the insect can become a serious pest through its introduction in any kind of barley or malt from an English source, contaminated, perhaps, many years ago and yet having not suffered any appreciable damage so far as could be ascertained. It is now certain, however, that much of the depreciation in malt which has occurred in past years has been attributed to causes other than the true one and the real offender has escaped blameless.

One of the most surprising facts relating to the economy of *Khapra* is its habit of hibernation. It can disappear into retirement

for long periods and return to the attack at unexpected intervals. It is exceedingly difficult to convince maltsters that this larva will continue to live for years without food and apparently without air, until they are shown collections of larvæ, varying from two or three to hundreds of specimens, perfectly sealed in whitewash blisters on the walls of kilns and malting floors, &c., where they must have lain for years. This singular property of longevity under starvation conditions would appear to be characteristic of insects belonging to the genus *Trogoderma*, a common example of which is the Museum beetle, *Trogoderma tarsale*.

Dr. J. W. Folsom, in his recent work, "Entomology with special reference to its Ecological Aspects,"* refers to observations made by Wodsdalek on a remarkable instance of such longevity. "Finding that larvæ of the common Museum beetle, *Trogoderma tarsale*, would live a long time without food, moulting meanwhile but not eating the cast skins, he tested their longevity by keeping them individually in glass vials without food. The larvæ gradually decreased in size to almost their length at hatching, but were surprisingly tenacious of life. Newly hatched larvæ that had never eaten lived four months without food; quarter-grown larvæ, fourteen months; half-grown larvæ, three years; three-quarters grown larvæ, four years; and full-grown individuals from four to five years. If stunted specimens were given food they began to grow again, and they could again be reduced in size by a second period of starvation. By alternate periods of feasting and fasting, larvæ were three times brought to their maximum size and three times reduced to their minimum size."

Wodsdalek's observations on the Museum beetle go a long way towards explaining the erratic results obtained in endeavouring to work out the life-history of *Khapra* as it is pursued under the abnormal conditions to which it is subjected in this country. The conditions found in maltings are entirely artificial, and under the different circumstances with regard to methods of storage and relative situations of kilns and bins, the behaviour of the creature will be correspondingly different in its periods of larval activity, hibernation, pupal rest and emergence. This makes it impossible

* JAMES MURRAY, London, 1923.

to say anything really definite about its life-cycle so far as periodicity is concerned. Under laboratory conditions its behaviour is equally puzzling. The writer has kept larvæ in Petri dishes without change for three years. The pupal stage, sometimes reported as having a duration of a few weeks, or even days, has also persisted with no signs of emergence throughout long periods, and may have been regarded as dead except for the following experience. At the Brewers' Exhibition in 1922, Messrs. Murphy & Son, Ltd., had on view a collection of grain pests among which was a set of specimens illustrating the life-stages of the *Khapra* beetle. Mounted on the card by means of seccotine were a number of beetles, larvæ, and a row of pupæ obtained from such experimental material as that mentioned above, and which from the length of time they had remained in that condition were regarded as dead. The pupæ consists of a semi-transparent skin derived from the final larval stage through which the maturing beetle can be easily observed. Sometime during the interval which has since elapsed the insects have made their escape, leaving only the thin pupal sheath attached to the card.

It is often puzzling to maltsters who have had the unfortunate experience of seeing great numbers of the larvæ, in that they have never seen the beetles which lay the eggs from which the hairy grubs emerge. This may be explained by several facts, the first being that the beetle is not larger than a quarter the size of the grub and it thus escapes observation, particularly as its dirty brown colour so perfectly matches malt debris, dust of any kind, and wooden floors. In the writer's experience they can always be found in the joints of the floor boards in maltings where the larvæ occur, and such places certainly provide the insects with a safe retreat. Minute larvæ are also found in the same situations and it is very likely indeed that the eggs are often deposited among the particles of grain which are always present in these places. Another reason is that the proportions of larvæ to perfect insects is enormously large owing to the prolific fecundity of the beetle and the long period of larval life compared with that of the mature insect. The latter appears to survive for the time required for oviposition and is comparatively short. Under experimental conditions they live

only a few days, and those insects found in the floors as mentioned above are rarely alive.

Another outstanding feature of the *Khaphra* beetle is its capacity for enduring high temperatures to a degree rarely found among living organisms. The *maximum* temperatures at which an organism will live, says Folsom (*loc. cit.*), has as its upper limit the *ultramaximum* at which the organism dies at once, probably because of the coagulation of proteids in the protoplasm. The ultramaximum temperature of some common insects is as follows :—Springtail (*Podura similata*), 36·0° C.; larva of fly (*Musca vomitoria*), 42·4° C.; silkworm (*Bombyx mori*), 45° C.; water boatman (*Notonecta*), 45° C., whereas the *Khaphra* beetle not merely withstands but appears to thrive at the anomalous temperature of 56° C. That it prefers this high temperature and can produce it by physiological processes in which the destruction of malt is involved is best illustrated by the conditions of the material in bins badly infested with the insect which always show a grain temperature of 112-120° F., a circumstance which has several times led to its discovery.

Not less difficult of interpretation is the relationship of *Khaphra* to moisture. After a paper read by the writer at a Meeting of the Institute of Brewing, in 1921,* a very interesting discussion on this aspect of the subject followed, in which Mr. H. Stanley Taylor, of Bath, expressed the opinion that *Khaphra* could not develop in dry malt (moisture below 2%) and that it required moisture derived from the atmosphere as supplied by moist walls, boards, &c. This was contrary to the author's experience that the *Khaphra* beetle *per se* raised the moisture content of the malt in which it was living from that say of 1·5% to so high a figure as 10%. In Mr. Taylor's capacity as a maltster, and as Director of a well-known brewery company, he has since that time had considerable experience of the insect, and has moreover carried out a number of laboratory experiments, the sequel to which is a modification of his previous views on this point. Mr. Taylor has communicated some valuable figures showing the rise of water content in stored malt which

* "Pests and Diseases of Barley and Malt. Part. I.—Injurious Insects." *Jour. Inst. Brew.*, XXVII., 1921, p. 346.

amply confirms the writer's earlier statement. It is not possible to include Mr. Taylor's interesting observations here, as they will be published elsewhere.*

With reference to the more practical aspect of eradication, Voelker has suggested a method of trapping which depends upon the ease with which the insect may be induced to creep into sacking and other fabric. This appears to be a ready and simple means of trapping, in which sacking is suspended from laths in such a way that the bottom edges of the fabric touch the top of the malt heap, the laths being attached to pulleys to allow of adjustment to height of malt, and to enable them to be put out of action when necessary. Voelker speaks of this method being very reliable, but, so far as the writer's observations lead him to believe, although not carried out to test this point, the only larvæ the fabric will attract are those not snugly esconced inside the malt corns. Of these, there are always immense numbers clinging to the outside of the grain stored in bins, and, when such grain is transferred to corked bottles or tubes, the insects at a "loose end" will always migrate to the bottom of the cork until it is covered with as many as it will take. In a Petri dish in which tissue paper has been placed between the malt and the top of the dish the insects will be found to have vacated their position on the outside of the grain to that of the dark corners of the folds of paper, but, in each case, the insects inside the corns remain there and it seems likely that they will always do so, so long as the corns provide them with food and shelter.

It is only of successful methods of eradication involving fumigation that the present writer can speak with experience, and of the various materials mentioned by Voelker, chloropicrin has yielded the most certain results.

* *Bulletin Bureau of Bio-Technology*, this issue, p. 113.

A Preliminary Note on Partial Soil Sterilisation for Bulb Growing

THIS investigation was commenced with the original intention of determining the effect of a steriliser applied to the soil in the control of Eel Worm (*Tylenchus*).

The Bulbs (*Narcissus*) were first of all sterilised according to the recommendations laid down by Ramsbottom, and subsequently planted in soil in which eel worms were observed to exist, and then subjected to the chemical treatment indicated below. Unfortunately, however, the bulbs and leaves in both the control and treated pots, after flowering, showed no indications of attack by eel worm, which was ultimately confirmed on examination under the microscope. Hence this particular part of the experiment gave no results from which any conclusions could be deduced.

Some interesting observations, however, were made upon the effect of the steriliser upon both foliage and root growth. The experiments were carried out in No. 12 size pots, each containing 12 lbs. of infected soil. The soil was treated (in the case of the liquid steriliser) by applying 100 cc.'s of the required concentration as evenly as conditions would allow, over the surface of the soil. In the case of the powder steriliser the requisite quantity was lightly forked into the surface of the soil. Equal quantities of water were given to each pot sufficient to make it damp, and this treatment (watering-in) was repeated during the ensuing 7 days.

The bulbs were then planted, one to each pot, 7 days after the soil treatment, and were kept under glass maintained at about 60° F. Daily observations were made in regard to development and appearance, flowering, etc., until the bulbs were actually lifted. No other treatment, manurial or otherwise, was applied. The sterilisers used were Alvesco No. 2 (liquid) and Alvesco Steriliser Powder.

	SOLUTION.										POWDER.			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Pot ...														
Date of Potting Soil ...	<.....						9.10.23							>.....
Date of Sterilising Soil ...	<.....						17.10.23							>.....
Date of Planting Bulbs ...	<.....						24.10.23							>.....
Date of Appearance of Shoot through Soil ...	2.1.24	28.12.23	1.1.24	25.1.24	28.12.23	22.1.24	22.1.24	1.1.24	18.1.24	24.1.24	22.12.23	—	28.12.23	28.12.23
Date of Actual Flowering	22.3.24	12.3.24	8.3.24	15.3.24	10.3.24	10.3.24	15.3.24	7.3.24	19.3.24	21.3.24	29.2.24	—	8.3.24	14.3.24
Difference in Days ..	80	75	67	50	73	48	43	66	61	60	67	—	71	77
Flowers, 1 Spike ...		9	9	9	10			10	11	8	11	—	10	9
Flowers, 2 Spike ...	1-10 1-4					1-3 1-3	1-5 1-5					—		
Length of Leaf ...	14½"	19"	22"	17"	18"	18"	16½"	21"	14½"	14½"	31½"	—	16"	22"
Date of Lifting ...	<.....						11.4.24							>.....
Concentrations of S.S. No. 2, per 100 c.c. ...	.066	.11	.16	.22	.55	1.11	1.66	2.22	.25 ozs.	.5 ozs.	1.0 oz.	2.0 ozs.		

OBSERVATIONS

1. From the general appearance of the roots, partial sterilisation seems to materially increase the growth of same, and this increase

would be expected to have a beneficial effect upon the plants in other directions, offering, as it does, a greater food-absorbing area.

2. There also appears to be some indication that the sterilisation may tend to induce earlier flowering, which would be an advantage from the commercial standpoint.
3. The root system in the treated pots appeared to be more sturdy and voluminous as compared with the "controls." The foliage and bloom were both luxuriant in colour and generally healthy in appearance.
4. These preliminary results appear to warrant further trials being carried out, and plans are being laid with a view to large scale experiments being started this autumn, both under glass and in the open.



PHOTOGRAPH. (Fig. 29).—Numbers at side indicate length of plants in feet, the largest plant being grown on sterilised soil, the smaller plants being controls.

T. P. and A. W. L.

FIG. 29

White Fly on Hops

IN connection with some experimental work which the writer has had under consideration, it was found necessary to grow a number of hop plants under glass. These were planted last autumn, and during the dormant period the house temperature was maintained at about 60° F. During this period chrysanthemums, young tomatoes and cucumbers were also grown, together with a selection of other flowering and decorative plants. In February of this year the hops began to show visible signs of growth, and the bine quickly made progress.

The White Fly, *A. vaporariorum*, was introduced into the house and allowed a free run. The pest quickly multiplied, and before very long all the plants, including the hops, became infested. As the hops increased in growth it was observed that the fly exhibited a partiality for this particular plant in preference to the others present in the house. At the time of writing (May) the condition of the hop plants is, to say the least, bad. Most of the leaves having lost their natural green colour. The undersides of the foliage are alive with both mature fly and scale, as shown in the accompanying photograph.

The upper sides of the foliage which have become contaminated with the familiar honeydew exuded by the fly is also covered with the peculiar "soot" fungus, *Fumago vagans*, as also shown in the photograph, Fig. 30.

It would, of course, be interesting to see if hops were similarly attacked in the open, because it seems possible that if given favourable climatic conditions this pest might be serious from the point of view of hop growers.

At the moment there does not appear to be any immediate danger in this respect, but Lloyd has shown that White Fly can withstand the conditions of a mild winter in the open, at any rate in the Lea Valley. In some districts this pest gives considerable trouble to growers of beans under glass, whilst in others no trouble has been experienced. There is, of course, a distinct difference in

the character of growth of plants grown under glass as compared with those cultivated in the open, and one wonders if in the former case there is some chemotropic influence at work which is not present, at any rate to the same degree, in the latter. There is also the possible influence of colour or shades of colour exerting an attractive stimulus upon the pest.

Unfortunately there is not a great deal known concerning the effect of such stimuli upon insect life, but the subject is well worth studying on account of its extreme interest, if not for its economic and scientific value.

T. P.



FIG. 30.

The Analysis of Ammonium Polysulphide Solutions

AMMONIUM Polysulphide (A.P.S.) was originally introduced by Salmon, of Wye, for controlling mould on hops.

Extensive trials, however, showed that it was not advisable to use it on certain varieties of hops, so that its principal use at present is for the control of apple mildew, rose mildew, and, to a limited extent, American gooseberry mildew, on which it has given very good results. The great advantage of this wash lies in the fact that very little deposit is left after use, which makes it suitable for spraying fruit just prior to picking, as it does not produce disfiguration—an important factor from the point of view of marketing.

The fungicidal value of A.P.S. depends on its polysulphide sulphur content, as was conclusively shown some years ago by Horton and Salmon in the case of lime-sulphur. The efficiency of A.P.S. depends also on its wetting and spreading properties, so that in order to obtain the best results, a spray spreader should be used (*Bulletin* No. 8, 252).

The control of the polysulphide content in manufacture is thus very important, and as the analysis of many batches of A.P.S. by the ordinary gravimetric bromine-oxidation method (Bloxam. *Trans. Chem. Soc.*, 1895, 277) or the direct weighing method of Küster and Heberlein (*Z. anorg. Chem.*, 1905, 53) is far too long a process for works purposes, the following rapid method was worked out:

20 cc. of the A.P.S. are diluted to a litre with freshly-boiled distilled water and the ammonia and sulphide sulphur determined in the ordinary way, the former by direct titration and the latter iodometrically. The polysulphide sulphur is the difference between total and sulphide sulphur. The sulphide sulphur figure is of importance in determining the stability of the diluted solution. This depends, of course, also on the nature of the water and the dilution used, but in general it is found that the

higher the ratio Total Sulphur/Sulphide Sulphur, the less stable is the solution. Thus 1 in 200 solutions of A.P.S.—the normal dilution for spraying purposes—in which the above ratio was 4.0, 3.5 and 3.0, were, after 1 hour, cloudy, slightly opalescent and clear, respectively.

For the determination of total sulphur the best oxidising agent was found to be ammoniacal hydrogen peroxide, and in principle the method consists in determining the ammonia in the ammonium sulphate formed. 25 cc. of the diluted A.P.S. are added, to a mixture of 20 cc. pure 10 vol. hydrogen peroxide and 10 cc. of .880 ammonia and allowed to stand for some minutes until the yellow colour has disappeared. The liquid is concentrated to a small volume until nearly all the free ammonia has been driven off and then exactly neutralised with N/1 acid, using methyl red, the volume of acid being noted. 20 cc. N/1 caustic soda are added, the liquid is again boiled down to a small volume and the excess of alkali titrated with standard acid. The amount of acid initially used corresponds to the trace of ammonia remaining after boiling and is subtracted from the amount of alkali required to decompose the ammonium sulphate. 1 cc. N/1 caustic soda is equivalent to .016 gm. sulphur. The results obtained agree well with gravimetric determinations and the time required is greatly reduced. It can be shortened still further by using the formaldehyde titration method for ammonium salts, which depends on the fact that when neutral formaldehyde solution is added to a neutral solution of an ammonium salt, hexamethylenetetramine is formed and the acid of the salt liberated.



This method is more rapid but not quite as accurate as the first, as the end-point is not very sharp, but if the method is standardised against pure ammonium sulphate and the volume of the solution to be titrated kept down, the results are accurate to within 0.2 to 0.3 per cent. The diluted A.P.S. is oxidised, exactly neutralised as above and cooled. 10 cc. 1+2 formalin solution, neutralised to phenolphthalein are added, the liquid is allowed to stand for 10 minutes and the liberated acid titrated to phenolphthalein, without further dilution of the solution. The correction for the acid initially used must, of course, be again applied.

N. K. S.

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